MEASURING THE IMPACT OF EARLY MATHEMATICS SUPPORT FOR STUDENTS ENROLLED IN AN INTRODUCTORY CALCULUS UNIT OF STUDY

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ABSTRACT

In this study we report data relating to a cohort of students who participated in support programs at our Mathematics Learning Centre or took part in mathematics bridging courses. The students were enrolled in an introductory calculus unit of study at our university, most of them starting Science degrees. Demographic data, performance data and attendance figures are presented with the aim of gauging the effect of the support. While the study is observational and so conclusions are tentative, the results are encouraging and support the efficacy of the assistance received with over three quarters of the Centre's attendees completing and passing the unit.

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INTRODUCTION

The need for mathematical support at university is now greater than ever as student cohorts become increasingly diverse, university entry requirements become more flexible and students' mathematical preparation and skills are seen to be significant factors in the retention and success for students in science and engineering, as well as in many other disciplines (Varsavsky, 2010). Support centres and facilities for assisting students in mathematical topics have been established in many universities in Australia, the United Kingdom and Ireland, amongst other countries. At our university, the Mathematics Learning Centre aims to assist eligible students to develop confidence and skills in mathematics and/or statistics, where eligibility means that students are undergraduate, enrolled in a first level mathematics or statistics unit and are demonstrably less well prepared for that unit than desirable. The Centre operates during the academic year, while students are studying, and is a free service provided to these students. Students can 'drop in' or attend small group tutorials and workshops. The University also offers bridging courses in mathematics, which are short intensive courses held in February, prior to the first semester. These bridging courses are open to all and are fee paying. They constitute 24 hours of class time held over 12 days.

Measuring and benchmarking the effectiveness of our practice for those of us who work in mathematics support is and always has been problematic. One challenge to evaluating such support is that there is no assessment for degree credit associated with support programs. As MacGillivray and Croft (2011, p.196) propose: 'the essence of learning support is that it is not formal'. Indeed, Godden and Pegg (1993) suggest that evaluation, in the traditional sense, may be incompatible with the successful conduct of tertiary mathematics support programs. Further, (eligible) students are educationally diverse and self-select whether to utilise a support centre. The questions: 'What constitutes success for bridging course students (Taylor & Galligan, 2006) and students using mathematics support centres?' and 'What is the role of that support in students' success?' are complex.

Some frameworks for evaluating mathematics support at various institutions include attendance data in programs and support facilities, performance of students in their mathematics units and qualitative data recording students' perceptions about the help they receive and its effect on their learning and confidence (Dowling & Nolan, 2007; Pell & Croft, 2008). Attendance data are a measure of demand and, since mathematics support programs are usually 'optional extras' for students, a measure of how well students' needs are being met (MacGillivray & Croft, 2011). Lawson, Halpin, and Croft (2001) suggest that counting return visits is a more sophisticated measure of the effectiveness of the mathematics support than simply attendance figures. Qualitative data from internal student feedback surveys provide insights into how the mathematics support is perceived by students themselves. This feedback is therefore an important indicator of effectiveness but has some limitations. As MacGillivray and Croft (2011) point out, it is rare to find negative feedback about mathematics support from the students who use it. Measures of effectiveness based on attendance or student feedback data have been characterised by Croft (2008) as ‘soft measures’. Measures characterised as ‘hard measures’ (Croft, 2008), are attempts to quantitatively measure the effect of mathematics support on student performance. Dowling and Nolan (2007) compared the examination success of ‘at risk’ students who attended their Mathematics Learning Centre (MLC) with those who did not. They claim that the MLC contributed directly to the retention of a significant number of ‘at risk’ students. Similarly, in a study of engineering students, Patel and Little (2006) showed that mean module scores for Mathematics Study Support (MSS) students were significantly greater than those for non-MSS students; an estimated difference of about 4%.

While we have used attendance and student feedback data for many years to inform our practice, in this paper we will examine student performance in an introductory calculus unit of study in an attempt to provide a ‘hard measure’ of its effectiveness. We do not claim direct causal links from the findings – our students are self-selecting and many variables that affect students’ performance, such as motivation levels, are unknown and cannot be controlled. Rather, as suggested by MacGillivray and Croft (2011), we present our findings as quantitative evidence of the value of mathematics support.

METHODOLOGY

The cohort we selected for this study were students enrolled in an introductory calculus unit of study as enrolment in this unit of study is restricted. It is not open to students who have previously completed either intermediate mathematics or advanced mathematics. That is, a student who has previously completed a course containing substantial calculus content may not enrol in this unit. Hence, while the mathematical preparation of this cohort includes students who may have completed studies in elementary mathematics in years 11 and 12 (General Mathematics for the HSC, that is Higher School Certificate in New South Wales), their mathematical backgrounds are not as diverse as in other mathematics units of study. All students enrolled in this unit are eligible to use the Mathematics Learning Centre.

Data were obtained for 176 students from the student database including demographic information, their degree program, whether they had studied General Mathematics for the HSC and their final mark in the introductory calculus unit of study. Information on student enrolment in the mathematics bridging course and total attendance in Mathematics Learning Centre programs was obtained from local databases. For some variables of interest information was available for only a subset of these students.

The data were analysed using *SPSS* (statistical software package) to gauge the effectiveness of the Centre’s support on students’ performance in their calculus unit. We reiterate that we do not claim causality.

RESULTS

DEMOGRAPHIC INFORMATION

Data were obtained for 176 students, 106 female (60%) and 70 male (40%). Most of these students (130, 74%) were between 18 and 21 inclusive, while 12 students (7%) were 30 or older. Ninety four percent of the students (166) were Australian domestic students.

Sixty nine percent of the students were enrolled in a variety of Science degrees. Students enrolled in Science programs are required to take 12 credit points of junior (1st year) mathematics or statistics, so enrolment in the introductory calculus unit of study constituted 50% of this requirement. Importantly, Science students who do not pass this unit cannot fulfil their mathematics requirements in that (standard academic) year. Seventy three students (41%) were known to have studied General Mathematics for their HSC, but no other information on prior mathematics was available for the remaining students.

Table 1 shows the final grades of students in 2010 in the introductory calculus unit of study.

Table 1: Unit of study grade (n=176)

Grade	Number	Percentage
Withdrawn	24	14
Discontinued, Fail	1	<1
Discontinued, Not Fail	3	2
Absent Fail	3	2
Fail	39	22
Pass	73	41
Credit	23	13
Distinction	10	6

MATHEMATICS BRIDGING COURSE ATTENDANCE

Mathematics bridging courses are preparatory courses that enable a prospective student to obtain prerequisite or assumed knowledge before commencing their degree program (MacGillivray, 2009). Accordingly, these courses represent the first opportunity for students to learn some of the mathematics assumed for their degree programs at our university. Further, our recent research (Gordon & Nicholas, 2012, in press) shows that students perceive these bridging courses not only as a resource to ameliorate previous difficulties with mathematics and learn new topics but also as an important part of their transition from school to university – 'a taste of the big time' – as one student put it.

The 2 unit mathematics bridging course introduces students to the concepts of differential calculus. Although the assumed knowledge for the introductory calculus unit of study was 'at least year 10 mathematics' and the unit is described as an 'introduction to differential and integral calculus[2], 26 students, about 15% of the cohort, attended the 2 unit mathematics bridging course.

There is evidence suggesting that attending a mathematics bridging course has a positive impact on retention in the unit of study. Table 2 shows that no mathematics bridging course attendee withdrew from their unit of study compared with 27 of the non-attendees, indicating that 18% fewer bridging course students withdrew from their unit of study compared to non-bridging course students. This difference is statistically significant (Fisher's exact test; $p = 0.016$).

Table 2: Student withdrawals from the unit of study for Mathematics Bridging Course students and other students

	Withdraw *	Completed	Total
Non-bridging course	27	123	150
Bridging course	0	26	26
Total	27	149	176

* includes students who discontinued, not 'fail'

For the 149 students who either completed the unit of study with a grade or were classified as absent fail or discontinued fail, the unit of study mark was, on average, 3.9 marks higher for the 26 bridging course attendees compared to those of the 123 non-attendees. However, this difference was not statistically significant ($t_{147} = 1.00$; $p = 0.32$).

ATTENDANCE AT MATHEMATICS LEARNING CENTRE SEMESTER PROGRAMS

The students in the introductory calculus unit of study were advised during their second lecture (and with a follow up email in Week 3) that there was a weekly support tutorial held at 8am on Thursdays at the Centre. Students were also informed that they were eligible to come to the 'Drop-in' Centre for assistance.

There were 56 students who attended the Mathematics Learning Centre (MLC) for more than 1 hour during the semester. In accord with Lawson, Halpin and Croft (2001) we will classify these students

[2] School of Mathematics and Statistics, Junior Mathematics and Statistics 2010 Handbook

as MLC attendees, as these students represent those who used MLC programs on more than one occasion. Males were under-represented with 32% (18) of the attendees being male.

Table 3 shows the final grades of the MLC attendees in the introductory calculus unit of study compared to students who did not attend the Centre.

Table 3: Unit of study grade for MLC attendees (>1 hour) and non-MLC students

Grade	MLC Attendees n = 56 Number (%)	Non-MLC students n = 120 Number (%)
Withdrawn	2 (4)	22 (19)
Discontinued, Fail	0 (0)	1 (1)
Discontinued, Not Fail	2 (4)	1 (1)
Absent Fail	0 (0)	3 (2)
Fail	7 (13)	32 (26)
Pass	36 (64)	37 (31)
Credit	7 (13)	16 (13)
Distinction	2 (4)	8 (7)

Table 3 indicates that only 4 MLC attendees (about 7%) did not complete the unit compared to 27 (about 23%) of non-MLC students (statistically significant: $\chi^2 = 6.21$, df=1, p=0.01). Moreover, about 80% (45) of the MLC attendees achieved a Pass grade or better, compared to approximately 51% (61) of the students who did not attend the MLC. This result is statistically significant ($\chi^2 = 13.89$ df=1, p<0.001).

One hundred and forty nine students either completed the unit of study with a grade or were classified as absent fail or discontinued, fail. There was evidence that the 52 MLC attendees achieved, on average, 5.8 marks more in their unit of study compared to the 97 students who did not attend the MLC (t = 2.17, df=145, p=0.03). Figure 1 shows the 95% confidence intervals for the mean marks of each group. Note that the width of each confidence interval depends on the number in each group and the variation within the group.

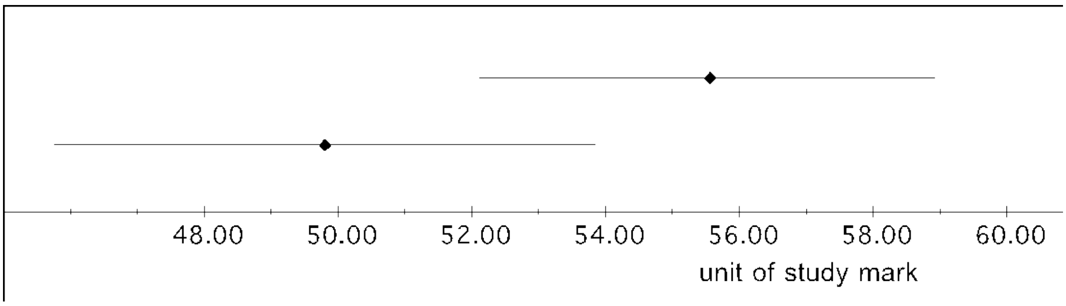

Figure 1: Confidence intervals for mean marks in the unit of study (upper interval: MLC attendees, lower interval: non-MLC attendees).

The fifty-two students who made up the MLC attendees were divided into two groups, depending on whether or not they attended for ten or more hours during semester. Students who attended MLC programs for ten or more hours are referred to as MLC frequent attendees. Table 4 breaks down the grades for these students according to the frequency of their attendance at the MLC.

There is strong evidence (from Table 4) that number of hours of MLC attendance was not independent of the grade achieved ($\chi^2_4 = 14.76$, p = 0.005). Further, about 92% of students who attended the MLC for 10 hours or more passed the unit of study compared to 82% of MLC attendees who did not attend as frequently and 63% of non-MLC students.

Table 4: Unit of study grade according to MLC attendance group

Unit of study grade	Number of hours (t) of attendance at the MLC			
	t ≤ 1 hour	1< t < 10	t ≥10	Total (%)
Fail	36 (24)	5 (3)	2 (1)	43 (29)
Pass	37 (25)	19 (13)	17 (11)	73 (49)
Credit or higher	24 (16)	4 (3)	5 (3)	33 (22)
Total (%)	97 (65)	28 (19)	24 (16)	149 (100)

Interestingly, 25% of the non-MLC students achieved a grade of credit or better, compared to about 21% of MLC frequent attendees and 14% of MLC attendees who did not attend as frequently. This, together with data from Table 2, suggests that there is a small group of high achieving (distinction) students enrolled in this unit of study for whom MLC assistance may not be necessary to pass the unit but who used the resource to improve their mathematics skills.

Figure 2 shows the 95% confidence intervals for the mean marks of each group. Note that the width of each confidence interval depends on the number in each group and the variation within the group.

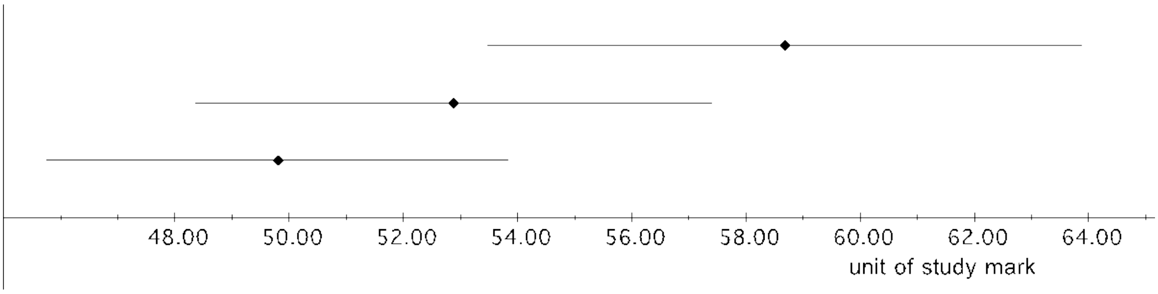

Figure 2: Confidence intervals for the mean marks: MLC frequent attendees (top), MLC less frequent attendees (middle) and non-MLC attendees (bottom)

Further, our analysis indicates a statistically significant linear relationship between total hours attended at MLC (if greater than 1 hour) and Unit of Study mark for the 52 students for whom these data were available ($t_{50} = 2.735$, $p = 0.009$). The equation suggests that about 13% of the variation in Unit of Study marks for MLC students is explained by the total hours students attended the Centre ($r = 0.36$). Hence the students who devoted more time to studying in the MLC benefitted from this accordingly.

DISCUSSION

The introductory calculus unit provided a useful context for evaluating the impact of mathematics support. The results suggest a relationship between students' usage of the MLC and their achievements in the introductory calculus unit. Further, higher hours of attendance at the Centre's programs are linked to better results. These findings indicate that a combination of student engagement with mathematics and appropriate support is favourable for success. There are also indications that retention is increased for mathematics bridging courses students; further research is needed to explore the impact of bridging courses and ongoing support on students' perseverance and retention in first level mathematics units.

One implication of our findings concerns the lack of participation by students who are 'at risk', yet fail to utilise the resources to help them, sometimes with unfortunate outcomes. In particular the disproportionally lower numbers of males attending the Centre's programs is a concern and requires further investigation.

Despite the challenges of evaluating mathematics support, the collection and analysis of a range of data – both soft and hard measures (Croft, 2008) – is important to mathematics support centres for a number of reasons. Firstly, for funding to such centres to continue, it is essential that evidence is presented on usage and other aspects (MacGillivray & Croft, 2011). Secondly, publications that disseminate the experiences and outcomes in one support centre can be useful to the many similar facilities in Australia and overseas. Our research and scholarship contributes to a community of practice in support centres.

CONCLUSION

As universities in Australia pursue policies of widening participation, the responsibility of providing effective support in mathematics is clearly part of an institutional ‘duty of care’ enabling students, whose previous opportunities to learn appropriate levels of mathematics were less than optimal, to succeed in their entry level degree units. The results presented here are encouraging and provide quantitative evidence of the value of mathematics support. Finally, as qualitative feedback reveals what is important to students participating in the support programs and why these aspects are important, we leave the last word with a student (in a written MLC survey):

It has increased my confidence in so many ways. Going over the fundamentals has filled so many huge gaps in my knowledge and allowed me to understand how things fit together in mathematics. I have always approached anything mathematical with fear and frustration and avoided these things wherever possible. … I now enjoy mathematics and the challenge of using the other side of my brain.

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